Bioacoustic Absorption Spectroscopy

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LONG TERM GOAL

Demonstrate the potential of bioacoustic absorption spectroscopy for tomographic mapping of the bioacoustic parameters of fish with swim bladders in shallow water.

OBJECTIVES

Develop a propagation model that accounts for the effects of bioacoustic absorptivity on transmission loss in shallow water at frequencies between 0.2 and 10.0 kHz. Develop a bioacoustic model that accounts for the resonance frequencies of absorption lines, which are due to dispersed pelagic fish, and schools of pelagic fish with swim bladders. Develop a model of the seasonal variability of resonance frequencies. Demonstrate consistency between absorptivity and echo sounder based estimates of number densities.

APPROACH

Design, construct and test an ultra broadband (0.2 – 10 kHz), light weight, long term, autonomous sources and receivers, that will permit long term monitoring of bioacoustic parameters. Conduct a series of bioacoustic absorptivity experiments in littoral seas in co-operation with fisheries biologists. These experiments will be designed to investigate the "signatures" of the two major classes of fish with swim bladders in time frequency space: physostomes (which have volumes that vary inversely with pressure) and physoclists (which have volumes that are independent of pressure).

Develop a transmission loss model that includes multiple bioacoustic absorbing layers with realistic shapes. Simulate effects of multiple absorbing layers on transmission loss vs. time and frequency of physostomes and physoclists. Apply model to new and previously published bioacoustic absorptivity measurements, derive bioacoustic parameters of sardines and anchovies and other fish, and demonstrate consistency with trawling data.

Invert bioacoustic parameters of anchovies from previously reported back-scattering data, which were made in concert with concurrent trawls in the seas off California, by matching theoretical computations with data. Demonstrate consistency between absorptivity and back-scattering based derivations of bioacoustic parameters. Continue to refine analysis of the causes of the differences between absorptivity and echo sounder based estimates of number densities of sardines in the Gulf of Lion.

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WORK COMPLETED:

I served as Chief Scientist of the first bioacoustic absorption spectroscopy (BAS I) experiment in the Santa Barbara Channel. The experiment was conducted in concert with the NMFS Southwest Fisheries Science Center at the end of September. We recorded 3 days of high quality broadband acoustic data. The broadband source and the receiving arrays worked well. The source and the receiving arrays were easy to deploy and recover (deployment: ~ 60 minutes and recovery: ~ 30 minutes). The signal to noise ratio was high over most of the frequency range. The trawling was successful. The site was dominated by anchovies, as expected. Fish concentrations were initially low, increased with time, and were quite high on the third day of the experiment. SWFSC scientist, David Demer's, analysis of multi-frequency echo sounder data permitted isolation of fish from plankton, and through near real time analysis of target strengths provided an independent means for estimating fish lengths. Calculations of resonance frequencies for anchovy lengths derived from trawling and TS data are shown in Figure 1.

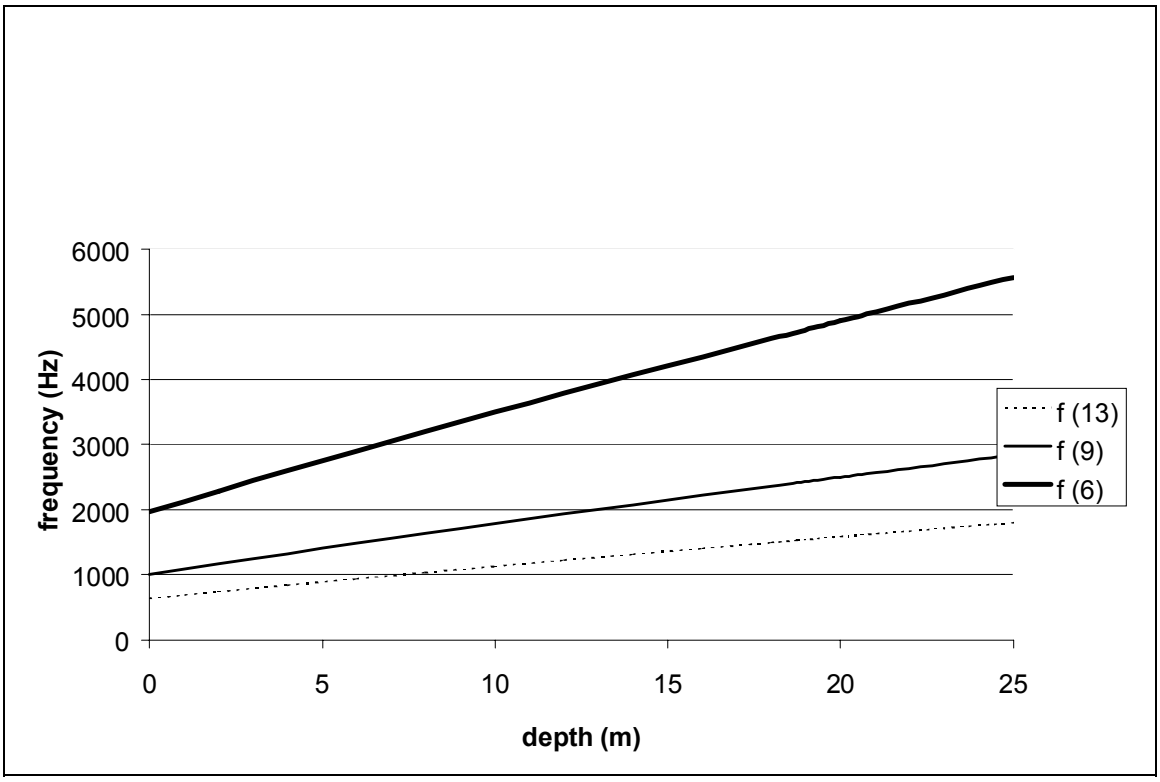

Figure 1. Calculated resonance frequencies of anchovies, based on a preliminary analysis of trawling (13 and 9 cm) and TS (14, 10 and ~ 6 cm) measurements during BAS I. The minimum mesh size was 1.25 cm; the frequencies of echo sounders were 38 and 120 kHz.

The peak at 13 cm corresponds to adult anchovies, and is consistent with historical measurements of this parameter. The peaks at 6 and 9 cm hypothetically correspond to "episodic" spawnings of juvenile anchovies, which were about 6 and 7 months old respectively (Butler, 1989). This is consistent with previously published bounds on lengths of juvenile anchovies in the Santa Barbara Channel in late September (5 – 10 cm).

RESULTS

In preparation for BAS I I analyzed Van Holliday's backscattering measurements from dispersed anchovies. Matching of calculations and measurements resulted in estimates of the relative number densities and ensemble Q's of year classes. Results, which are shown in Figure 2, suggest that juveniles are characterized by multiple absorption lines.

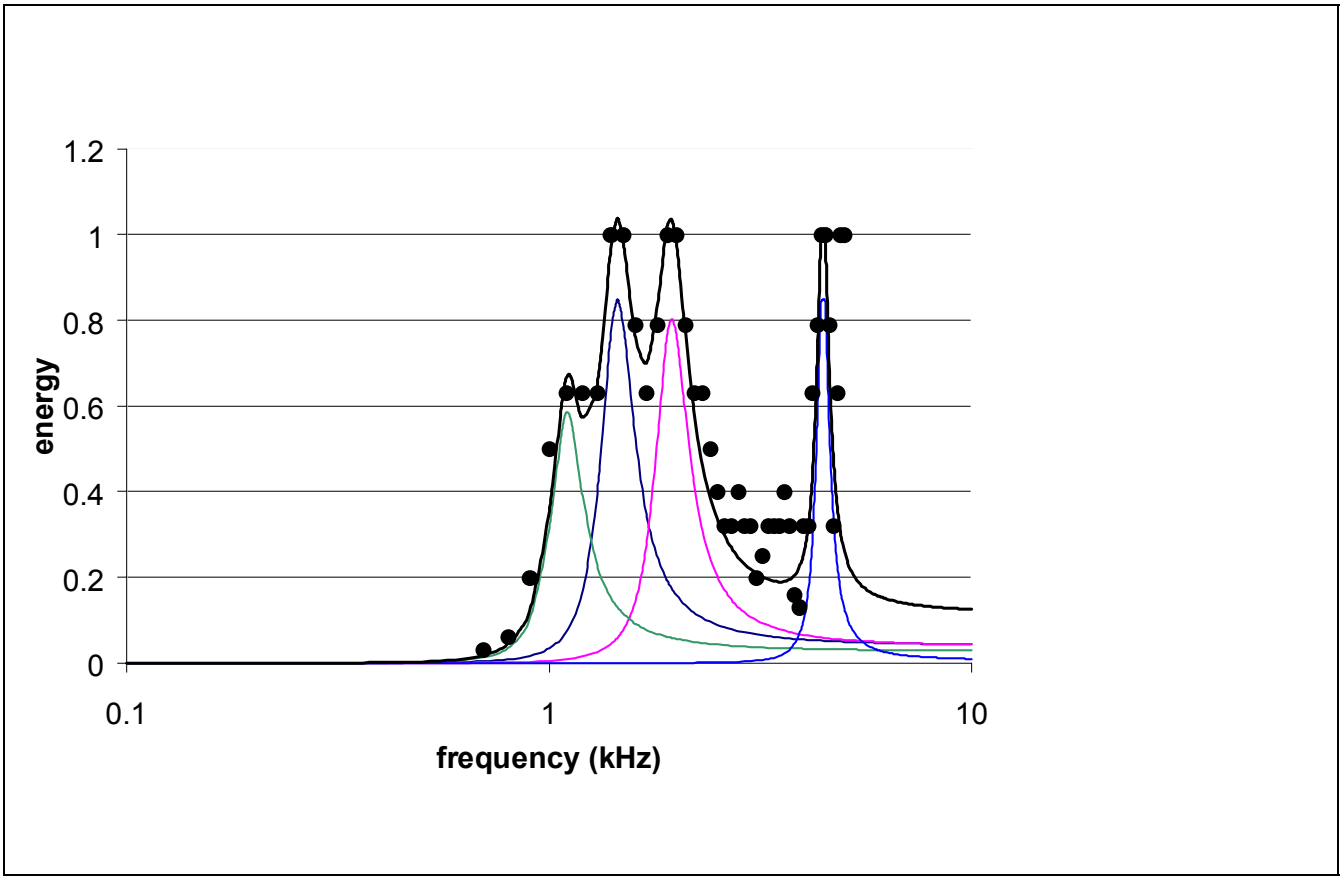

Figure 2. Measurements (●) due to Holliday (1972) and calculations of back-scattered energy vs. frequency. Resonance frequencies of 4.45 (blue), 1.95 (red), 1.45 (blue) and 1.10 (green) kHz correspond to 0.25, 2.25, 3.25 and 4.25 year old dispersed anchovies. Heavy solid line represents the sum of contributions from year classes. Absorption lines at 3.6 and 5.0 were not modeled, in the interest of clarity. Closely spaced peaks at 3.6, 4.45 and 5 kHz are hypothetically associated with juvenile anchovies.

This interpretation is consistent with previously reported results, which indicate that spawning of anchovies is "episodic". According to Butler (1989), several "episodes" generally occur in each spawning season. A similar pattern of absorption lines may be expected in BAS I data. A refereed paper that documents the results of this analysis will be published in the Journal of the Acoustical Society of America in 2001.

IMPACT / APPLICATIONS

Naval significance: This research suggests that the detection range of naval tactical sonars may be significantly reduced when operating in shallow water environments where large numbers of pelagic fish are present. Strategically important areas, where fish concentrations may be particularly high, include the shallow seas off the coasts of the United States, Europe and China.

Fisheries applications: These results suggest that bioacoustic absorptivity can be used to estimate number density (biomass) of pelagic fish with swim bladders in littoral environments, and to classify fish by length.

TRANSITIONS

Naval Research Laboratory (NRL) is supporting a three year 6.2 research program to conduct experimental and theoretical investigations on the effects of bioacoustic absorptivity on transmission loss in littoral seas. This research program started in FY 00.

RELATED PROJECTS

Southwest Fisheries Science Center: biological sampling and fisheries sonar programs.

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PATENTS

The Naval Research Laboratory has applied for an international patent on my design of low cost, large bandwidth, lightweight, autonomous source and receiver arrays. These systems are specifically designed to permit bioacoustic absorption spectroscopy measurements to be made between a fixed broadband source and multiple, widely spaced fixed receiving arrays in littoral seas.